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Impact of Post Peak Daily Metabolizable Energy Intake on Performance of Broiler Breeder Hens

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ABSTRACT

One hundred ninety two broiler breeder hens, from 40 to 49 weeks of age, were utilized in a precision feeding study for determining the hens' energy requirement. Treatments were daily feed allotments containing metabolizable Energy Requirement (ER) estimated by empirical model, *ER* minus 10 (ER–10), plus 10 (ER+10), and plus 20 kcal hen^{-1} d^{-1} (ER+20). Four levels of Metabolizable Energy Intake (MEI) were made by adding 0, 1.2, 2.4 and 3.6 grams corn oil, over the top of daily feed allotment. All birds consumed the same amount of diet, and were provided the same intake of nutrients, except energy. Hens with weight gain of 3.5 g per day had the maximum reproductive performance. Ovary weights were lower in *ER*-10 hens. This difference was also reflected in Small Yellow Follicle (SYF), and Large Yellow Follicle (LYF) numbers, in which the ER-10 hens had fewer SYF (7.6) and LYF (1.1). Hens that received 462.7 kcal d^{-1} (ER), produced 4.04 eggs more than those that received 452.7 kcal d^{-1} (ER–10). However, addition of extra 10 and 20 kcal (ER+10, ER+20) on daily MEI had no beneficial effect on egg production. Using the linear broken line model, the ME requirements for egg production and hatchability were estimated at 458.5, and 456.2 kcal hen^{-1} d^{-1}, respectively. Comparing the current estimated requirement value with earlier reports revealed that broiler breeder hens need more energy in a commercial house than those kept in an experimental house in the cage or pen. In conclusion, during post peak period with average 458.5 kcal MEI, 5 kcal hen^{-1} d^{-1} more than Ross 308 recommendation can improve broiler breeder hens' performance.

Keywords: Egg production, Hen's energy requirement, Ross 308, Yellow follicle.

INTRODUCTION

Actual requirement for any nutrient needs to be fully understood in order to know the potential risk in production when trying to reduce feed costs and develop appropriate margins of safety. Research in the area of the energy requirements has been focused on estimating the energy requirement for laying hens, while for broiler breeder hens' information is slowly being developed (Reyes *et al*., 2011). Energy requirement of a broiler breeder hen during the laying period is a function of the potential reproductive performance of the bird, of its rearing condition, especially the birds' density, and of the environment in which the bird is kept (Leeson and Summers, 1984; Richards and Proszkowiec-Weglarz, 2007). Consequently, the task of calculating daily feed allocations that will maximize profit over the different phase of laying cycle is extremely difficult.

Broiler breeders are parents of broiler chickens and selected for rapid growth rate. Parallel to selection for fast growing, their appetite for feed increases significantly. In this case, they receive restricted amount of feed during a day and they don't have free access to feed for controlling body weight and access to optimum reproductive

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performance. After the peak of egg production, when the ratio of maintenance to production requirement gradually increases, precision and accurate feed allocation is a big challenge of flock manager. However, few publications have addressed the energy requirements of broiler breeder hens during the post peak period. Rabello *et al*. (2006), in an experiment, compared use of the recommended feeding program for Hubbard Hi-Yield broiler breeder hens with a model. Their results indicated that the model estimated value was better matched with breeder hen's requirements than strain management guide's recommendation. Most researches developed a simple factorial approach or model for predicting energy requirement exclusively for the entire production cycle (Reyes *et al*., 2011; Romero *et al*., 2009; Sakomura, 2004; Rabello *et al*., 2006). However, the system is more complex than can be addressed by a unique model, because of the changing potential performance and state of the birds over time. Therefore, the objective of the present study was to investigate the impact of daily metabolizable energy intake on the performance of broiler breeder hens during post peak period (40 to 49 weeks), in a practical condition.

MATERIALS AND METHODS

One hundred ninety two broiler breeder hens (Ross 308) and sixteen males, from 40 to 49 weeks of age, were utilized in a precision feeding study for determining the hens' energy requirement in commercial farm condition. Trial was done in a commercial farm in the north of Iran (36° 54.758 ´N, 49° 28.758´ E, at 475 m altitude). Hens were selected from 4,700 healthy birds according to very similar body weight (3550±20 g) and were distributed between 16 floor pens (2.2×1 m) which were made by metal wire net in the middle part of the same house. The pens were littered with wood shavings. Density of birds (5.45 birds m^{-2}), ratio of male to female (1 male per 12 females), and other rearing protocols were the same as non-experimental birds in the house. Each experimental pen was equipped with manual trough feeder and one bell drinker. Water was made available *ad libitum* throughout the experiment. Feed was restricted and the total allocation of diet was placed in the trough feeders in each pen at the start of the photoperiod. Feed clean up time was measured once a week. The 14:10 hours L:D photo schedule was performed during the ten-week experiment. An ambient temperature of 20 to 22°C was maintained by controlled ventilation and heating. All birds in the house (experimental and non-experimental birds) were vaccinated against Newcastle disease, using Lasota strain through drinking water, once a month.

Experimental Treatments

Basal corn-soy layer diet (2791 kcal kg^{-1}, 14.8% CP) was used during the ten-week experiment (Table 1). Four levels of daily Metabolizable Energy Intake (MEI) by hens were applied as experimental treatments. Levels of *MEI* were made by adding 0, 1.2, 2.4 and 3.6 grams corn oil (8300 kcal kg^{-1}) per hen, over the top of daily feed allotment of each pen. Basal diet was mixed by horizontal mixer before adding corn oil. Corn oil was added and mixed with daily feed allotment of each pen in a bucket before feed distribution.

Daily feed allotment was determined according to sum of energy requirements for body weight maintenance, bird activity, weight gain and egg production. Energy requirement estimated by the modified equation of Reyes *et al*. (2012), the equation variables was set according to average weekly experimental flock performance. Modification of Reyes *et al*. (2012) model was done by using 1.2 coefficient for maintenance component of the model (Rabello *et al*., 2004), because their equation was set for breeders kept on the cage, but in the present trial birds were reared on the floor. Each treatment group of hens received

Table 1. Composition of hen's basal diet[a].

Ingredients	Hens diet (g kg^{-1})
Corn grain	689
Soybean meal	210
Wheat bran	10
Dicalcium phosphate	14
Oyster shell	68
NaCL	3.5
Vit and Min supplements [b]	5
DL-Methionine	0.5
Calculated Nutrients (%)	
AME_n (kcal kg^{-1})	2791
Crude protein	14.8
Calcium	2.9
Available phosphorus	0.35
Na	0.15
Dig Lys[c]	0.63
Dig Met	0.26
Dig M+C	0.47
Dig Thr	0.47
Dig Arg	0.82

[a] As-fed basis. [b]Vitamin and mineral premix provided the following per kilogram of diet: Vitamin A, 11,000 IU; Cholecalciferol, 3,500 IU; Vitamin E, 100 IU; Vitamin k3, 5 mg; Vitamin B12, 0.03 mg; Biotin, 0.3 mg; Folacin, 2 mg; Niacin, 55 mg; Pantothenic acid, 15 mg; Pyridoxine, 4 mg; Riboflavine, 12 mg; Thiamine 5 mg. Copper (as cupric sulfate $5H_20$), 10 mg; Iodin (as calcium iodate), 1.2 mg; Iron (as ferrous sulfate $4H_20$), 50 mg; Manganese (as manganese oxide), 120 mg; Selenium (as sodium selenite), 0.3 m ; Zinc (as zinc oxide),110 mg. [c] Calculated amino acid composition is reported on a standardized ileal digestible amino acid basis (Amino Dat 4.0).

one of the following energy content feed: estimated energy requirement minus 10 kcal (ER–10), Estimated Requirement (ER), and estimated requirement plus 10 (ER+10), and 20 (ER+20) kcal per day. Thus, all birds consumed the same amount of basal diet, and were provided the same intakes of protein, minerals, and vitamins, but the energy intakes were different (Table 2). Males received a standard male diet (2,750 AMEn kcal kg^{-1}; 12% CP; 0.45% dig Lys; 0.43% dig M+C; 0.7% Ca; 0.35% aP). Nutrients and metabolizable energy content of feed ingredients were analyzed by near infra-red spectroscopy, before feed formulation.

Measured Traits

At the end of each week, all of the hens of each experimental unit were individually weighed before feed distribution to obtain the average empty body weight. Daily records were kept of the total number of eggs laid, and the numbers of double yolked, cracked, small (lighter than 50 g), dirty, misshapen and broken eggs, and the number of eggs suitable for incubation. The average weight of single yolked eggs and yolk fractional weight were determined on one day of each week. At 47 week of age, hatchable eggs were stored at 18ºC for five days before incubation, and hatchability was determined.

A drop of blood was obtained from three birds from each pen at 49 weeks of age by superficial venipuncture of a wing vein, and the proportions of 17 ß-estradiol (with an RIA kit automatic biochemical analyzer, Hitachi 7600-020, Hitachi Co., Tokyo, Japan), High Density Lipoprotein (HDL), Low Density Lipoprotein (LDL), TriGlyceride (TG), and cholesterol were determined (Hitachi 717, Hitachi Co., Tokyo, Japan).

At the end of the experimental period, 8 hens per feeding regimen were selected randomly and anesthetized for necropsy. Liver, abdominal fat pad, and ovaries were collected at necropsy. Weight of liver, ovaries, and abdominal fat pad were divided by BW/100 to estimate their fractional contribution. Ovaries were weighed (after removing hierarchical follicles) and follicles were classified into 2 groups: hierarchical follicles (Large Yellow Follicles, LYF; > 8 mm), and small yellow follicles (2 to 8 mm), according to the system devised by Gilbert *et al*. (1983).

Table 2. Daily *MEI* (kcal) of broiler breeder hen during 40 to 49 weeks of age.[a]

Treatment		Age (Week)										Average daily *MEI* (kcal)
		40	41	42	43	44	45	46	47	48	49	
MEI[b,c]	ER−10	448.3	450.2	449.7	454.6	453.7	452.6	454.3	454.3	454	455.3	452.7
	ER	458.3	460.2	459.7	464.6	463.7	462.6	464.3	464.3	464	465.3	462.7
	ER+10	468.3	470.2	469.7	474.6	473.7	472.7	474.3	474.3	474	475.3	472.7
	ER+20	478.3	480.2	479.7	484.6	483.7	482.7	484.3	484.3	484	485.3	482.7

[a] Energy requirement estimated by modified equation of Reyes *et al*.,(2012) ($ME_{kcal/hen/day}= (BW^{0.75}_{kg}\times 111.9-0.46$ ambient $T^{°C})\times 1.2 + 5.8$ Weight $Gain_{g/d}$ +2.3 Egg $Mass_{g/d}$) variables set according to average weekly experimental flock performance. [b] *ER*, *ER*−10, +10, +20 were estimated requirement, estimated requirement minus 10, plus 10 and 20 kcal, respectively. [c] *ME* intake increased by adding 0, 1.2, 2.4 and 3.6 grams corn oil, over the top of daily feed allotment.

Statistical Analyses

The experimental design was a completely randomized design with four treatments each replicated four times. Egg production was analyzed as the number of total eggs laid and hatching eggs on a weekly hen house basis and per hen placed at the start of experiment. Hatchability was expressed as a percentage of eggs set. Means for hatchability less than 10 eggs were excluded from the analysis. Mortalities at different ages or period were analyzed as the percentage of the birds present in each pen at the beginning of the experiment.

The data were analyzed by the general linear models procedure of the SAS 9.0 (2002) software with pen means as the experimental unit. Parameters which measured weekly were analyzed as repeated measures using PROC MIXED of SAS software (SAS Institute, 2002). The age was used as one of class variables for examining the interaction between age and *MEI* on measured parameters. Significant treatment effects were separated by Duncan's multiple range tests.

Linear and nonlinear functions were derived for graded levels of daily MEI. Fitted linear and nonlinear models (Schutte and Pack, 1995) and broken line regression as described by Robbins *et al*. (2006) were used for estimating the metabolizable energy requirement.

RESULTS

Although the house temperatures were mechanically kept constant, slight fluctuations occurred throughout the trial. The overall registered min and max temperatures were 19.5, and 23.5°C, respectively. Daily MEI had no significant effect on the time until the trough feeder was empty, at all ages. MEIs (kcal hen^{-1} d^{-1}) of broiler breeder hen during 40 to 49 weeks of age are presented in Table 2.

Average empty body weights at the sampling ages for each treatment are presented in Figure 1. Effect of daily MEI on weekly body weight gain of broiler breeder hens were significant (P< 0.01) at all ages measured.

A significant (P< 0.01) treatment effect was found for total number of hen house eggs produced by broiler breeder during 40 to 49 weeks of age (Table 3). A similar result was observed for total number of hen house hatching eggs (Table 4; P< 0.03). Data presented in Table 5 show that during the ten-week experiment, the egg weights were not affected by treatments.

Fractional yolk weight, postovulatory follicle number and oviduct weight were not affected by *ME* intake (Table 6). Treatment changed number of LYF and SYF (P< 0.09; P< 0.07), but had no effect on the number of LWF. *ME* intake showed significant effect on ovary weight and number of double yolk egg (Table 6; P< 0.04; P< 0.03). Hens that received higher amount of energy had more abdominal fat (Figure 2; P< 0.04). Liver fractional weight did not differ among treatments (Figure 3). Figure 4 shows that increasing the level of MEI decreased hatchability at 47 weeks of age (P< 0.002).

Notably, 17 ß-estradiol concentrations, determined in samples at 49 weeks of age, were affected by level of energy intake (P< 0.02). No treatment effects were found for blood LDL, HDL, TG and cholesterol concentrations (Table 7). No interaction was found between age and MEI on measured traits.

Fitted quadratic model estimated metabolizable energy requirement for total hen house egg production during the post peak production (40–49 weeks) was 470.8 kcal d^{-1} (Table 8). One slope, broken-line analysis of total hen house egg production regressed on the MEI indicated that 458.5 kcal d^{-1} was required for the optimal egg production of broiler breeder hens (Table 8, Figure 5). Quadratic equation for total hen house hatching egg, reached its maximum at 468.8 kcal MEI (Table 8). According to quadratic and broken line model, estimated metabolizable energy requirements for hatchability were 458.7 and 456.2 kcal d^{-1},

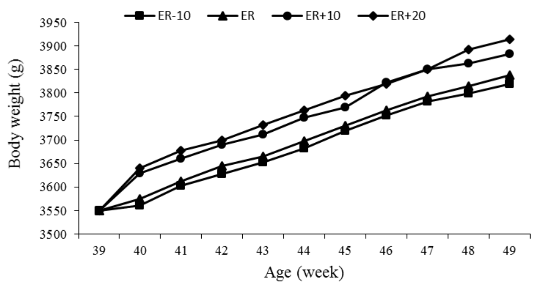

Figure 1. Effect of daily MEI on weekly body weight gain (g) of broiler breeder hen (from one week before the start of experiment until 49 weeks). *ER*, *ER*–10, +10, +20 were estimated requirement, estimated requirement minus 10, plus 10 and 20 kcal, respectively.

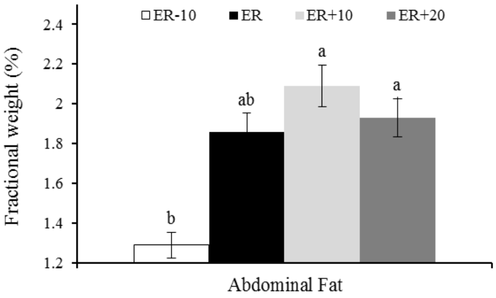

Figure 2. Effect of daily MEI on abdominal fat (P< 0.04) fractional weight in broiler breeder hen (at 49 weeks). Mean with no common letter are significantly different (P< 0.05). *ER*, *ER*–10, +10, +20 as in Figure 1.

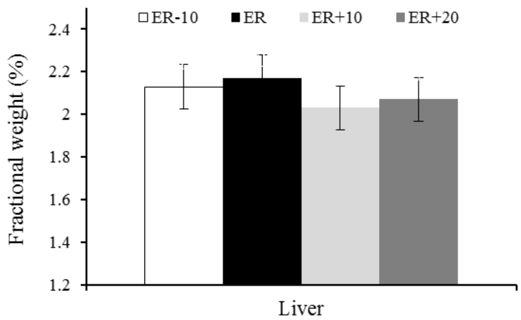

Figure 3. Effect of daily MEI on liver fractional weight (P> 0.74) of broiler breeder hen (at 49 *weeks*). *ER, ER*–10, +10, +20 as in Figure 1.

Table 3. Effect of daily MEI on number of hen house eggs produced by broiler breeder during 40 to 49 weeks of age.[a]

Treatment		Age (Week) 40	41	42	43	44	45	46	47	48	49	Total HHE[A]
MEI[C]	*ER*–10	5.97	5.40^{b}	5.70	5.20^{b}	5.25	5.30	5.42	5.05^{b}	5.25	4.57^{ab}	52.66^{b}
	ER	6.22	5.97^{a}	5.77	5.60^{ab}	5.50	5.50	5.40	5.57^{a}	5.60	4.93^{a}	56.70^{a}
	ER+10	5.95	5.75^{ab}	5.55	5.87^{a}	5.67	5.57	5.57	5.60^{a}	5.25	4.45^{b}	55.22^{a}
	ER+20	5.92	5.72^{ab}	5.60	5.80^{a}	5.25	5.62	5.27	5.45^{ab}	5.57	4.85^{ab}	55.02^{a}
SEM		0.15	0.12	0.14	0.14	0.14	0.2	0.12	0.14	0.13	0.13	0.62
P value		0.53	0.07	0.72	0.02	0.16	0.68	0.45	0.07	0.17	0.09	0.01

[a] Means within the same column with no common superscripts are significantly different (P< 0.05). [b] Number of Hen Housed Egg production. [c] *ER, ER*–10, +10, +20 as in Table 2.

Table 4. Effect of daily *MEI* on number of hen house hatching eggs produced by broiler breeder during 40 to 49 weeks of age.[a]

Treatment		Age (Week) 40	41	42	43	44	45	46	47	48	49	Total HHHE[B]
MEI[C]	ER–10	5.87	5.33	5.69	5.12^{b}	4.87	4.87	5.06	4.83	4.95	4.39^{b}	50.88^{b}
	ER	6.16	5.93	5.73	5.58^{a}	5.06	5.12	5.16	5.41	5.33	4.83^{a}	55.02^{a}
	ER+10	5.87	5.69	5.52	5.83^{a}	5.45	5.25	5.14	5.33	5.04	4.27^{b}	53.41^{a}
	ER+20	5.87	5.69	5.60	5.64^{a}	4.94	5.12	4.83	5.24	5.12	4.58^{ab}	52.66^{ab}
SEM		0.15	0.13	0.15	0.14	0.18	0.19	0.13	0.16	0.09	0.09	0.70
P value		0.48	0.09	0.79	0.02	0.18	0.60	0.35	0.11	0.14	0.01	0.03

[A] Means within the same column with no common superscripts are significantly different (P< 0.05). [B] Number of Hen Housed Hatching Egg production. [C] *ER, ER*–10, +10, +20 as in Table 2.

Table 5. Effect of daily *MEI* on weekly egg weight (g) of broiler breeder hen (40–49 weeks).[a]

Treatment		Age (Week) 40	41	42	43	44	45	46	47	48	49	Mean
MEI[b]	ER–10	62.8	63.2	63.9	64.6	64.6	65.3	65.6	66.2	66.5	66.9	65.0
	ER	61.6	62.0	64.0	64.0	64.1	65.0	65.2	65.7	66.3	66.8	64.5
	ER+10	62.9	63.1	64.0	64.7	64.8	65.5	65.8	66.2	66.4	66.9	65.0
	ER+20	60.5	60.7	63.6	64.1	63.9	64.9	65.2	65.7	66.4	66.9	64.2
SEM		0.79	0.76	0.70	0.54	0.45	0.47	0.45	0.44	0.41	0.41	0.47
P value		0.15	0.13	0.96	0.73	0.53	0.82	0.76	0.76	0.99	0.99	0.56

[a] Means within the same column with no common superscripts are significantly different (P< 0.05). [b] *ER*, *ER*–10, +10, +20 as in Table 2.

Table 6. Effect of daily *MEI* on number of double yolk egg, yolk fractional weight and ovarian morphology of broiler breeder hen (at 49 week).[a, b]

Treatment		DY	YFW at 43 W	YFW at 46 W	LYF	SYF	POF	OVA (g)	OVI (g)
MEI[C]	ER–10	0.00^{b}	30.0	31.4	5.66^{b}	9.6^{b}	3.83	65.6^{c}	73.6
	ER	1.00^{ab}	30.0	31.3	6.62^{ab}	15.7^{a}	3.25	75.8^{ab}	72.3
	ER+10	1.75^{a}	30.5	31.3	7.00^{a}	18.2^{a}	3.14	84.8^{a}	66.4
	ER+20	0.00^{b}	30.4	31.1	6.50^{ab}	17.6^{a}	2.87	70.5^{b}	67.6
SEM		0.42	0.36	0.42	0.32	1.6	0.31	4.3	0.13
P value		0.03	0.70	0.95	0.09	0.07	0.28	0.04	0.36

[A] Means within the same column with no common superscripts are significantly different (P< 0.10). [B] Where, DY: Number of hen house Double Yolk egg, YFW: Yolk Fractional Weight, LYF: Number of ovarian Large Yellow Follicles, SYF: Number of ovarian Small Yellow Follicles, POF: Post Ovulatory Follicles, OVA: Ovary weight, OVI: Oviduct weight. [C] *ER, ER*–10, +10, +20 as in Table 2.

Table 7. Effect of daily MEI on broiler breeder blood parameters (49 weeks).[a]

Treatment		17 ß Est (pg ml^{-1})	LDL (mg dl^{-1})	HDL (mg dl^{-1})	TG (mg dl^{-1})	CHO (mg dl^{-1})
MEI[b]	ER–10	389.3^a	74.6	56.1	904.9	311.7
	ER	240.7^b	61.1	74.6	1010.6	350.9
	ER+10	238.1^b	73.6	53.8	809.2	289.3
	ER+20	227.6^b	51.5	64.5	788.5	273.7
SEM		39.3	7.9	6.2	58.4	12.5
P value		0.025	0.15	0.10	0.08	0.07

[a] Means within the same column with no common superscripts are significantly different (P< 0.05). [b] *ER, ER*–10, +10, +20 as in Table 2.

Table 8. Regression analysis of Hen House Egg (HHE), Hen House Hatching Egg (HHHE) production and Hatchability of egg (Hatch) on daily ME intake and estimated energy requirement (40–49 weeks).[a]

Traits	Model [b]	Regression Equation	*P* value	R^2	Estimated requirement (kcal hen^{-1} d^{-1})
HHE	Q	$Y= -2073.2+9.04x-0.009x^2$	0.047	0.42	470.8
	OSBL	$Y= 55.55-0.0867(458.5-x)$	0.005	0.48	458.5
HHHE	Q	$Y= -2432.1+10.595x-0.0113x^2$	0.05	0.41	468.8
	OSBL	Failed to converge	-	-	-
Hatch	Q	$Y= -9819.3+43.206x-0.0471x^2$	0.0005	0.71	458.7
	OSBL	$Y= 76.44+0.713(456.2-x)$	0.0005	0.70	456.2

[a] Model parameter's estimated by least square method of GLM procedure of SAS software. Two slope broken line failed to converge for all cases. [b] Where, Q: Quadratic, OSBL: One Slope Broken Line.

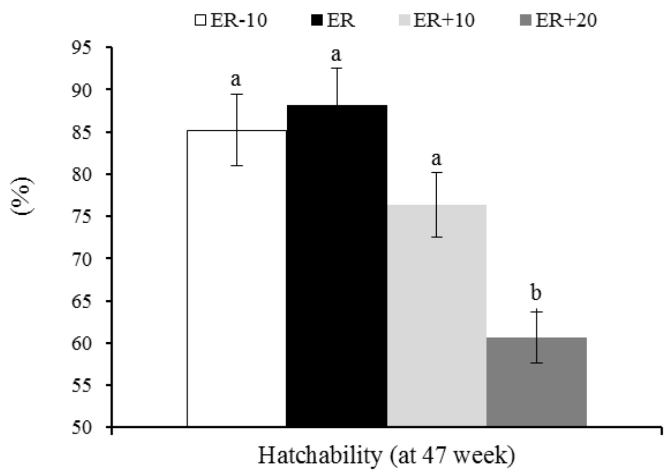

Figure 4. Effect of daily MEI on hatchability (P< 0.002, SEM 3.61) of broiler breeder hens egg (at 47 week). Mean with no common letter are significantly different (P< 0.05). ER, ER–10, +10, +20 as in Figure 1.

respectively. Two slope broken line failed to converge for measured traits.

DISCUSSION

The overall registered min and max temperatures during the ten-week trial, were 19.5 and 23.5°C, respectively. A discussion about the ideal thermal environment inside a house should include considerations of a specific zone where the temperatures allow the bird to expend the least amount of maintenance energy for thermogenesis. In a precision study and using birds which were electronically identified, Pereira and Naas

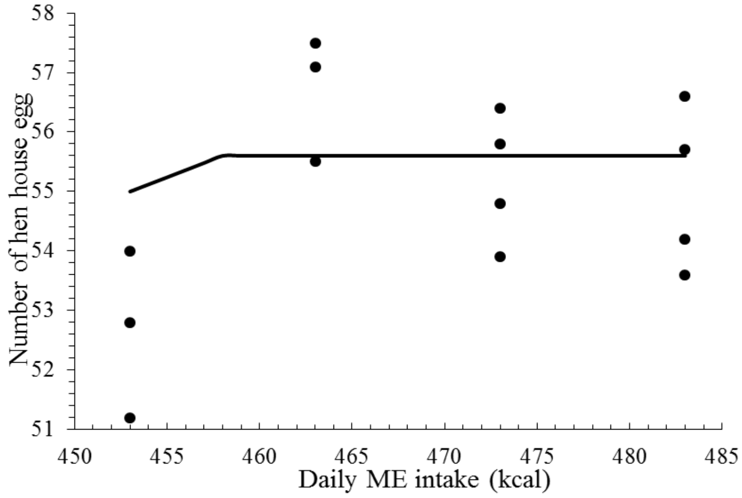

Figure 5. One slope broken line regression of hen house egg production on MEI (kcal d^{-1}) of broiler breeder hen (P< 0.005) from 40 to 49 weeks of age. *Y= 55.55-0.0867(458.5-x)*, Estimated energy requirements= 458.5 (kcal hen^{-1} d^{-1}), R^2= 0.48.

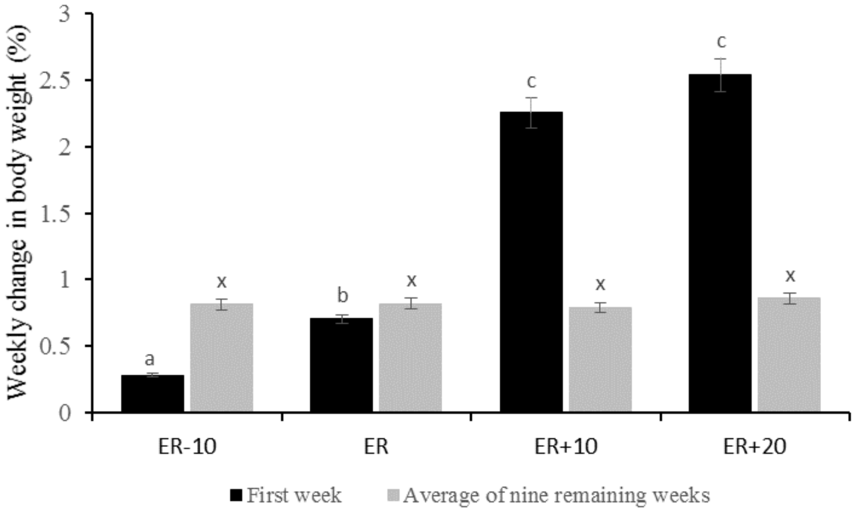

Figure 6. Effect of daily MEI on weekly change in body weight of broiler breeder hen from 40 to 49 weeks of age. Mean with no common letter are significantly different (P< 0.01). *ER*, *ER*–10, +10, +20 as in Figure 1.

(2008) estimated the thermo neutral zone for female broiler breeders. These researchers suggested that the lower and upper ranges were between 18.5 and 29.5°C. In many models for predicting *ME* requirements of breeder hens, 23°C is defined as a thermo neutral zone (Reyes *et al*., 2012; Sakomura 2004). It seems that in the present experiment, temperature range of 19.5-23.5°C was not an effective parameter in the energy requirement.

The mean feed clean up time over all treatments was 3 hours and 20 minutes. It means that, in the present trial, consumption of 30 kcal more (482.7 kcal d^{-1}, ER+20) and less (452.7 kcal d^{-1}, ER-10) *ME*, had no significant effect on the time until the trough feeder were empty. This observation implied that, in practical condition, when the change in diet energy is small, clean up time is not a valuable tool for assessment of energy status of broiler breeder hens. However, Moradi *et al*. (2013) diluted the energy of broiler breeder hens' diets by ten percent, and observed significant change in feed clean up time.

Increasing daily MEI increased body weight gain of broiler breeder hens (P< 0.01). Hens that received 452.7 (ER-10), 462.7 (ER), 472.7 (ER+10), and 482.7 kcal d^{-1} (ER+20), gained, respectively, 270, 287, 332 and 365 g during the ten-week experiment (Figure 1). Figure 6 shows that, in the *ER*+10 and *ER*+20 groups, most of the weight gain (80 g, 24.1%; 90 g, 24.6%) took place at the first week of introducing dietary treatments, while first week weight gain for *ER*-10 and *ER* groups were 10 g, 3.7% and 25 g, 8.7%, respectively. Results presented in Table 3 suggest that maximum egg output was achieved by 462.7 kcal MEI per day (ER group), therefore, it is concluded that 3.5 g d^{-1} weight gain is necessary for maximizing reproductive performance during 40 to 49 weeks of age. Ross 308 (2007) performance objective recommended 2.1 g gain per day at 40 weeks, but at 2011 recommended weight gain increased to 2.8 g d^{-1}. It seems that with intensive genetic selection and increasing broiler growth rate, required weight gain by their parents during rearing and lay will be increased.

Table 2 shows that calculated daily ME requirement increased from 40 to 49 weeks of age. These observations are inconsistence with general acceptance about withdrawal of feed after post peak production (Aviagen Group Ltd., 2011; Sun and Coon, 2005; Lien and Hess, 2009). Rabello *et al*. (2006) observed that 67% of the total MEI was for maintenance, 29% for egg production, and 4% for weight gain. Tables 3 and 5 indicated that average egg mass decreased 15% during the 10-week experiment. On the other hand, Figure 1 shows that body weight increased 8% in the same period. Therefore, energy need for egg production decreased (20 kcal), while maintenance and weight gain energy increased (26 kcal). Obviously, the balance between three components (maintenance, weight gain, and egg production) will be positive and requirement slightly increased.

Table 3 shows a significant treatment effect on total egg produced during 40 to 49 weeks of age (P< 0.01). So, hens that received 462.7 kcal per day (ER) produced 4.04 eggs more than hens that received 452.7 kcal per day (ER-10). However, addition of extra 10 and 20 kcal (ER+10, ER+20) on daily MEI had no beneficial effect on egg production. Using the linear broken line model, the *ME* requirements for egg production was estimated at 458.5 kcal per day, during the 40 to 49 weeks of age (Table 8, Figure 5). Estimated value from the experiment herein is relatively close to those from model of Rabello *et al*. (2004). In contrast, our estimation was higher than values reported by Rabello *et al*. (2006), Sun and Coon (2005), Reyes *et al*. (2012), and Sakomura *et al*. (2004). All the mentioned studies were done in an experimental house (in cage or pen), but current study was conducted in a commercial house. Ross 308 management guide at 40 and 49 weeks of age recommended 461 and 446 kcal *ME*/hen per day, respectively (Aviagen Group Ltd. 2011). Sakomura *et al*. (2004), and Ross 308 performance objective (Aviagen Group Ltd. 2011) at the same period reduced 2 and 1.5 kcal each week, respectively. In a practical condition, with competition for feed, more activity or movement, more energy requirement for antibody production due to vaccination, and lower atmospheric oxygen due to dust and ammonia, slower ME withdrawal is required (Zaghari *et al*., 2011). Interestingly, hens that received 462.7 kcal per day (ER), produced 5 eggs more than the standard of Aviagen Group Ltd. (2011), so, this observation further confirmed that slower withdrawal of *ME* will improve breeder hen's performance. Rabello *et al*. (2004) stated that birds raised on floor had 21.8% higher *ME* requirement for maintenance than those in cages, probably due to the energy expenditure for physical activity.

As shown in Table 8, use of quadratic models resulted in higher estimates of *ME* requirements than linear broken line model. Pesti *et al*. (2009) stated that quadratic model overestimate the requirement. Therefore, an appropriate and reliable model should be used to analyze dose-response data (Robbins *et al*., 2006).

Data shown in Table 4 indicate that the trend for hatching or settable eggs were relatively the same as total eggs. Birds reach the maximum settable eggs production by receiving 462.7 kcal per day (ER). However, addition of extra 10 and 20 kcal (ER+10, ER+20) on daily MEI slightly decreased number of hen housed hatching eggs. Other investigators reported that increase in feed allocation increased egg abnormalities including soft shell and double yolk eggs (Taherkhani *et al*., 2010; Chen *et al*., 2006).

Neither egg weight nor yolk fractional weight were affected by the range of MEI used in the present experiment. This finding is inconsistent with those reported by Taherkhani *et al*. (2010) and Chen *et al*. (2006). They observed increase in yolk and egg weight, probably due to increase in feed allocation, but in the current study, feed allocation was constant while the MEI increased. Van Emous *et al*. (2015) determined the effects of different dietary protein levels during rearing and different dietary energy levels during lay on reproduction of the modern Ross 308 broiler breeders. They concluded that feeding birds the high ME diet decreased egg weight during the second phase of lay. Joseph *et al*. (2000) observed a greater effect of daily crude protein intake than MEI on egg weight.

In the comparison of all birds, the abdominal fat pad of the *ER*-10 (1.29%) hens represented a lesser proportion of body weight than it did in the other hens (ER, 1.86%; ER+10, 2.09%; ER+20, 1.93%; Figure 2). Renema *et al*. (2004) reported that 61week old caged breeder hens managed on 3 body weight profiles had mean abdominal fat pad values of 4.46% (low curve) to 5.69% (high curve). In a comparison of genetic strains at 53 weeks of age, mean fat pad mass has been reported to be 4.8 to 4.9% of body weight (Joseph *et al*., 2002). Therefore, fatness did not appear to be the case in the present study. Parallel to this observation, data for liver fractional weight did not show significant change (Figure 3).

The oviduct weight was very consistent among hens of all MEI groups, averaging 69.9 grams (Table 6). This fits previous observations about similarities in oviduct weight across body size and feed allocation groups (Renema *et al*., 1999). However, ovary weight was lower in *ER*-10 hens compared with the other treatment groups of hens (ER, ER+10, ER+20, Table 6). This difference was also reflected in SYF and LYF numbers, in which the ER-10 hens had fewer SYF (7.6) and LYF (1.1). Renema *et al*. (1999) suggested that a naturally high incidence of SYF atresia may limit the ability of the ovary to generate an adequate number of LYF. Allocation of adequate nutrients, especially the energy to support ovarian follicle production, could be necessary for increased number of small follicle (Wilson *et al*., 1995; Hocking *et al*., 1987; 1989; Heck *et al*., 2004; Hocking and Robertson, 2005; Taherkhani *et al*., 2010; Onagbesan *et al*., 2006). This would explain the reduced ovary size, SYF and LYF productions in hens that received lowest amount of energy (ER-10).

Figure 4 shows that hens that received 462.7 kcal d^{-1} (ER) had higher hatchability compared to hens that received 452.7 kcal d^{-1} (ER-10), but those that received the highest amount of energy (ER+20) had the lowest hatchability at 47 weeks of age. Van Emous *et al*. (2015) reported that a high-energy or low-energy diet compared to a standard diet during the first phase of lay slightly decreased total and settable egg numbers, while a high-energy diet during the second phase of lay increased hatchability and number of saleable chicks.

Data presented in Table 7 shows that ER-10 hens with lower rate of laying had higher blood 17 ß-estradiol. Concentration of plasma 17 ß-estradiol indicated that ovarian development was potentially dissimilar between the *ER*-10 hens and those fed higher amount of energy (ER, ER+10, ER+20, Table 7) at 49 weeks of age. Report on plasma estradiol is controversial. Renema *et al*.

(1999), Onagbesan *et al*. (2006) and Moradi *et al*. (2013), reported that there was a significant relationship between peak plasma estradiol concentration and egg production. Hocking and Bernard (2000) reported that plasma estrogen in females broiler breeder was high at 24 and lowest at 30 weeks of age, after which it increased. Onagbesan *et al*. (2006) reported that although there was a significant relationship between peak plasma estradiol concentration and egg production, plasma concentrations of estradiol before and after peak egg production were not correlated with subsequent egg production levels. These differences in plasma estradiol concentrations also indicate the need to better understanding of the comparative endocrine relationships between different MEI groups in the post peak period by collecting more frequent samples.

Four levels of caloric intake had no significant effect on blood LDL, HDL, TG and cholesterol concentrations (Table 7). Chen *et al*. (2006) demonstrated that in feed-satiated broiler breeders hepatic de novo lipogenesis increased. Therefore, positive balance of energy did not appear to be the case in the present study.

In conclusion, during 40 to 49 weeks of age, with average 458.5 kcal MEI, (5 kcal hen^{-1} d^{-1} more than Ross 308 recommendation) and low withdrawal rate, it would be possible to improve broiler breeder hens' performance.

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اثر میزان انرژی قابل سوخت و ساز دریافتی روزانه بعد از اوج تولید بر عملکرد مرغ-های مادر گوشتی

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چکیده

در این آزمایش تعداد ۱۹۲ قطعه مرغ مادر گوشتی سویه راس ۳۰۸ از سن ۴۰ تا ۴۹ هفتگی برای تعیین نیاز انرژی روزانه بعد از اوج تولید تخم‌مرغ مورد استفاده قرار گرفتند. تیمارها شامل مصرف خوراک روزانه، معادل نیاز انرژی برآورده شده، ۱۰ کیلوکالری کمتر، ۱۰ و ۲۰ کیلوکالری بیشتر از مقدار برآورد شده بودند. چهار سطح انرژی قابل سوخت و ساز مصرفی روزانه با افزودن ۰، ۱/۲، ۲/۴ و ۳/۶ گرم روغن ذرت به مقدار جیره روزانه هر مرغ حاصل شد. مقدار خوراک مصرفی تمام مرغ‌ها یکسان بود. بنابراین مقدار دریافتی تمام مواد مغذی به غیر از انرژی برابر بود. نتایج نشان داد مرغ‌هایی که ۳/۵ گرم در روز افزایش وزن داشتند بیشینه عملکرد تولید مثلی را داشتند. تخم‌دان مرغ‌هایی که ۱۰ کیلوکالری انرژی کمتر در روز دریافت نموده بوند، سبک‌تر بود. کاهش وزن تخم‌دان در نتیجه کاهش تعداد فولیکول‌های سفید کوچک و فولیکول‌های زرد بزرگ بود. مرغ‌هایی که معادل نیاز برآورد شده در روز انرژی دریافت نموده بودند نسبت به گروهی که ۱۰ کیلوکالری انرژی کمتری دریافت نموده بودند ۴/۰۴ تخم مرغ بیشتری تولید نمودند. مصرف ۱۰ و ۲۰ کیلوکالری انرژی مازاد تاثیر معنی‌داری بر تولید تخم‌مرغ نداشت. با استفاده از تابعیت خط شکسته نیاز انرژی قابل سوخت‌وساز برای تولید تخم-مرغ و قابلیت جوجه درآوری ۴۵۸/۵ و ۴۵۶/۲ کیلوکالری در روز برآورد گردید. مقایسه نتایج پژوهش اخیر و تحقیقات گذشته که در قفس و پن‌های آزمایشی انجام شده است، نشان داد که در شرایط آشیانه‌های تجاری نیاز انرژی مرغ‌های مادر گوشتی بیشتر است. همچنین نتایج به دست آمده حاکی از این بودکه نیاز انرژی مرغ‌های مادر گوشتی بعد از اوج تولید، ۵ کیلوکالری بیشتر از مقدار توصیه شده توسط راهنمای پرورش سویه تجاری راس ۳۰۸ است.